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# Alterations in Knee Kinematics and Dynamic Stability Associated With Chronic Ankle Instability

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***Context:*** Chronic ankle instability (CAI) has been previously and separately associated with deficits in dynamic stability and proximal joint neuromuscular alterations, but how the 2 factors relate is unclear.

***Objective:*** To examine the contributions of lower extremity kinematics during an assessment of dynamic stability in participants with CAI.

***Design:*** Repeated-measures case-control design.

***Setting:*** Research laboratory.

***Patients or Other Participants:*** Thirty-eight volunteers were categorized into groups of those with unilateral CAI (10 men, 9 women; age = 20.3 ± 2.9 years, height = 1.77 ± 0.1 m, mass = 76.19 ± 13.19 kg) and those without (10 men, 9 women; age = 23.1 ± 3.9 years, height = 1.72 ± 0.1 m, mass = 72.67 ± 16.0 kg).

***Intervention(s):*** Participants performed 10 jump landings on each limb with a rest period between test limbs.

***Main Outcome Measure(s):*** Ankle plantar flexion, knee flexion, and hip flexion were captured with an electromagnetic tracking device at the point of ground impact. Ground reaction force data were used to calculate time to stabilization in the anteroposterior and mediolateral planes.

***Results:*** For the anteroposterior plane, we found a group-by-side interaction ($P = .003$), with the injured side of the CAI group demonstrating reduced dynamic stability. For knee flexion, a group main effect ($P = .008$) showed that the CAI group landed with less knee flexion than the control group.

***Conclusions:*** Diminished dynamic stability and decreased knee flexion angle at initial contact were apparent in the CAI group and may play a role in contributing to CAI. This altered kinematic pattern may influence preventive and therapeutic interventions for those with CAI.

***Key Words:*** dynamic postural control, time to stabilization, neuromuscular control, jump landings

**Key Points**

- During a single-limb landing task, participants with chronic ankle instability displayed increased time to stabilization in the anteroposterior direction on the injured side.
- Those with chronic ankle instability also demonstrated decreased sagittal knee-flexion angle at initial ground contact.

Lateral ankle sprain is one of the most common injuries among athletes and in the general population,[1] with an estimated daily injury rate of 1 in 10 000 people.[2] Yearly costs for the management and treatment of ankle injuries have been estimated to be greater than $2 billion.[3] Among those sustaining a first-time injury, the recurrence rate of ankle injury among active individuals is reported to be as high as 80%.[4] Altered ankle function due to repeated disruptions in the structural integrity of the ankle, with resultant perceived and observed deficits in neuromuscular control and mechanical stability, has been described as chronic ankle instability (CAI).[5]

It has been reported that CAI is associated with deficits in dynamic postural control as quantified through measures of lower extremity reaching distance using the Star Excursion Balance Test,[6–8] kinematic and kinetic assessments of jump landing,[9,10] and the ability to create stability after landing from a jump.[11–15] Although these measures have consistently exposed deficits in measures of dynamic postural control related to CAI, most investigators have not quantified the contributions of the ankle, knee, and hip in completing the dynamic postural control task. Yet the few groups[7–10] that have examined these relationships showed a consistent alteration in proximal joint kinematics in the limbs of those with CAI.

Landing from a jump is an activity that incorporates the inversion and plantar-flexion motions at the ankle that are associated with possible mechanisms of ankle injury.[16] Previous researchers[9–13,17–19] have demonstrated differences in landing patterns and force distributions among participants with and without ankle instability during jump landings. A novel technique employed in the measure of dynamic stability during a jump-landing task is time to stabilization (TTS). The TTS is the time required for the ground reaction forces exhibited after landing from a jump to stabilize within a range similar to that exhibited during a stable, single-limb stance. Reported TTS values vary, but the technique has demonstrated consistent sensitivity in screening for differences related to ankle instability.[11–14,18,19]

Joint kinematics have been used to determine the individual joint contributions to dynamic tasks in those with CAI. In recent years, investigators have shown that knee and hip joint kinematic patterns are altered in the presence of ankle instability. Gribble et al[7,8] reported reduced hip- and knee-flexion angles among volunteers with CAI during the Star Excursion Balance Test. During a jump-landing task, Caulfield et al[9] reported increases in knee-flexion and ankle-dorsiflexion angles in participants with functional ankle instability.

Table 1. **Foot and Ankle Disability Index (FADI) and FADI Sport Scale (FADI Sport) Scores for the Chronic Ankle Instability and Control Groups (Mean ± SD)**

| Group | FADI, % | FADI Sport, % |
|---|---|---|
| Chronic ankle instability[a] | 89.3 ± 2.03 | 74.8 ± 4.1 |
| Control | 100.0 ± 0.00 | 100.0 ± 0.00 |

[a] To be included in the chronic ankle instability group, a participant needed to score <90% on the FADI and <80% on the FADI Sport.

Altered proximal joint movement patterns may provide insight as to why those experiencing CAI exhibit increases in "giving way" and instability, leading to disruptions in function. Time to stabilization provides a consistent means of demonstrating differences in function associated with CAI, but it does not indicate why the stabilizing capability of the affected limb has changed. A kinematic pattern altered during assessment of TTS will provide insight regarding injury mechanisms and potentially correctable functional deficits that may be related to contributions of the lower extremity joints during landing. Therefore, the purpose of our study was to examine the TTS while simultaneously quantifying sagittal-plane kinematics of the ankle, knee, and hip at the point of ground contact during the landing phase of a jumping task. We selected initial ground contact as a critical time point for investigation of the injurious mechanisms associated with ankle sprain during landing tasks.[20] Because alterations in lower extremity sagittal-plane kinematics have been linked with deficits in other dynamic tasks,[7–9] we selected sagittal-plane kinematics for quantification in this investigation.

## METHODS

### Participants

Thirty-eight individuals volunteered and signed an informed consent form approved by the institution's review board, which also approved the study. Individuals with self-reported vestibular disorders or mild head injury in the previous 6 months were excluded from the study. Participants were categorized into either the unilateral CAI group (10 men, 9 women; age = 20.3 ± 2.9 years, height = 1.77 ± 0.1 m, mass = 76.19 ± 13.19 kg) or the control group (10 men, 9 women; age = 23.1 ± 3.9 years, height = 1.72 ± 0.1 m, mass = 72.67 ± 16.0 kg).

All volunteers participated in at least 30 minutes of exercise 3 times per week. Participants in the control group were free of any history of lower extremity injury and were matched by sex, age, height, mass, and limb dominance (determined as the leg with which they would kick a ball) to members of the CAI group. Then the limbs of the control participants were matched to those of the CAI group by designating the same "injured" and "uninjured" legs as in each matched CAI participant. For instance, if a CAI volunteer had an injured right side, the matched "injured" side of the control volunteer was also the right side. This helped to avoid potential issues of unmatched comparisons of limb dominance that would have occurred with randomized limb assignment in the healthy group.

Participants in the CAI group experienced no injury to the lower extremity other than the ankle. They had a history of at least 1 acute lateral ankle sprain that resulted in swelling, pain, and temporary loss of function (but none in the previous 6 months), with at least 2 episodes of the ankle "giving way" in the past 3 months.[7,8] Volunteers in this group were not participating in a rehabilitation program at the time of the study.

All participants completed the Foot and Ankle Disability Index (FADI) before being included in the study. The questionnaire, which quantified self-reported disability and deficits in ankle function, consisted of 2 parts that assessed instability during various forms of daily and physical activities: the FADI and the FADI Sport Scale. These instruments had high intersession reliability as indicated by the intraclass correlation coefficients (FADI ICC [2,1] = 0.98; FADI Sport ICC [2,1] = 0.94), and moderate to high sensitivity for detecting group and side differences related to CAI (FADI: $P < .05$, effect size = .62; FADI Sport: $P < .05$, effect size = .95).[21] We reported results of the FADI and FADI Sport as percentages. Inclusion criteria for the CAI group required a score of less than 90% on the FADI and less than 80% on the FADI Sport.[21] Participants in the control group were required to score 100% on both sections for inclusion in the study. Group means for the FADI and FADI Sport are found in Table 1.

### Instrumentation

During the jump-landing procedures, ground reaction force and kinematic data were collected and synchronized with an electromagnetic tracking system (Flock of Birds; Ascension Technology Corp, Burlington, VT) integrated with the force plate (model NC-4060; Bertec Corp, Columbus, OH) using MotionMonitor software (version 7.0; Innsport Inc, Chicago, IL). Ground reaction force data in the anteroposterior and mediolateral directions sampled at 200 Hz were used to calculate TTS variables. Although this sampling rate is lower than that typically used for collecting ground reaction force data during landing, it was the rate used by Colby et al[22] in their original description of TTS calculation. Similar ranges of sampling rates have been used by several recent groups[11–14,23] reporting TTS values, making the sampling rate of 200 Hz appropriate. Kinematic data were sampled at 100 Hz.[24] The MotionMonitor software was used to calculate ankle plantar flexion, knee flexion, and hip flexion at the point of ground impact.

### Procedures

Participants reported to the research laboratory for testing. First, we assessed vertical jump height to determine each volunteer's target during the jump-landing trials. Standing reach height was measured as the participant stood next to a Vertec vertical jump tester (Sports Imports, Columbus, OH) and reached up and touched the highest point possible while keeping both feet flat on the ground. Maximal double-limb vertical jump was measured as the participant touched the highest point possible; 3 trials were performed. Maximum vertical height ($Vert_{max}$) was identified as the difference between the maximum height reached during the 3 jumps and the standing-reach height.[22,23] We used this value to designate a target for the volunteers to reach during the jump-landing trials.

The jump-landing task consisted of a double-leg take-off jump with a single-limb landing. The double-limb take-off started from a point 70 cm from the center of the force plate with an attempt to reach for the target height of 50% $Vert_{max}$ with the Vertec positioned directly over the force plate. Landing occurred with the designated testing limb on the force plate, which was positioned flush with the testing surface.[11–14,23]

As soon as contact was made with the force plate, the participant was instructed to attempt to gain stability with only that leg and assume a single-leg balance position with the hands on the hips as fast as possible. The volunteer was asked to obtain and maintain the position for a 5-second period, beginning at the point of contact with the ground. If the participant hopped or touched down with the non-test leg in an attempt to gain stability, the trial was discarded and repeated.

Volunteers were allowed 5 minutes of rest between the maximal jump trials and the test trials. After the task was explained and demonstrated by the primary investigator, the order of the testing limbs, which was randomized, was revealed. Participants were afforded as many practice trials on the first designated testing limb as needed to make sure they felt comfortable with the task. Another 5-minute rest period was provided after the practice trials. Ten test trials were performed on the first testing leg, with 2 minutes of rest between trials. After the test trials were completed on the first testing leg, a 10-minute rest period was provided. The testing procedure was repeated with the second designated testing limb.

During the jump-landing task, electromagnetic tracking sensors were placed over the superior sacrum, mid-lateral thigh, mid-lateral shank, and dorsum of the foot using double-sided tape or neoprene straps with hook-and-loop tape (or both). A fifth sensor was attached to a stylus and used for digitizing the body segments. The first testing limb was digitized and the testing procedures completed before the sensors were transferred to the second testing limb to repeat the process.

## Data Processing

The TTS values in the anteroposterior (APTTS) and mediolateral (MLTTS) directions were calculated from ground reaction force data collected during the landing trials. Ground reaction force data were filtered with a third-order Butterworth filter with a cutoff frequency of 14 Hz.[23] The TTS variables were created with the sequential estimation method, using an algorithm to calculate a cumulative average of the data points from the jump-landing trials in a series by successively adding 1 point at a time.[11,22] To determine the values for the calculation of the cumulative average of the series (sequential average of the series), the first 2 raw data points from the trial were averaged, then the first 3 raw data points were averaged, then the first 4 data points were averaged, and so on. These sequential averages were then compared with the overall series mean.[11,22] The overall series mean was the mean of all the raw data points collected during the 5-second period after impact with the force plate. The participant was considered to be in a stable position when the sequential average of the series was within 0.25 SD of the overall series mean.[11,22]

Kinematic variables were determined using the Grood-Suntay angle orientation function in the MotionMonitor software. The following segments were defined in the calculation of the kinematic variables: sacrum, thigh, shank, and foot. In all kinematic variable creations, the proximal segment served as the reference frame in the software setup to create representations of the ankle, knee, and hip joints. The location of segment endpoints for estimating ankle and knee joint centers was performed using the centroid method in the software. The location of hip joint centers was calculated using the Davis method in the software. Raw data were filtered with a low-pass, third-order Butterworth filter with a cutoff frequency of 20 Hz.[25] The time point for data selection was designated at initial impact with the force plate, when the threshold voltage of the force plate registered more than 10 V. For each individual and for each side, the kinematic variables were normalized to a neutral stance position to account for individual variations away from a "true" neutral joint position. Specifically, the kinematic positions of the ankle, knee, and hip at ground impact were demeaned from the number of degrees away from 0° of ankle dorsiflexion, knee flexion, and hip flexion during the neutral stance collected during the digitizing process.

## Statistical Analysis

For all dependent variables, means and SDs from the test trials were compared. Separate 2 × 2 repeated-measures analyses of variance with independent variables of group (CAI, control) and side (injured, uninjured) were used to examine each dependent variable (APTTS, MLTTS, ankle plantar flexion, knee flexion, and hip flexion). In the event of statistically significant interactions, a Scheffé post hoc test was applied. All statistical analyses were conducted using SPSS (version 15.0; SPSS Inc, Chicago, IL). Statistical significance was set a priori at $\alpha < .05$.

Based on the means and SDs, effects sizes were calculated for the post hoc pairwise comparisons using the following formulas to calculate the Cohen d[26]:

Interaction effect:

$$d = \frac{\text{Injured CAI mean} - \text{Injured control mean}}{\text{Injured control SD}}$$

Group main effect:

$$d = \frac{\text{CAI mean} - \text{Control mean}}{\text{Control SD}}$$

Side main effect:

$$d = \frac{\text{Injured mean} - \text{Uninjured mean}}{\text{Uninjured SD}}$$

For interaction effects, the reported effect sizes reflect the selection of the injured side of the CAI group and the "injured" side of the control group for the 2 mean scores and SD values. The interpretation of the calculated values followed the scale provided by Cohen of small, moderate, and large effect sizes.[26] Additionally, 95% confidence intervals (CIs) were calculated for the mean values using SPSS.

**Table 2a. Time to Stabilization for the Chronic Ankle Instability and Control Groups in the Anteroposterior and Mediolateral Directions**

| Direction | Group | Time to Stabilization, s | |
|---|---|---|---|
| | | Mean ± SD | 95% Confidence Interval |
| Anteroposterior | | | |
| | Chronic ankle instability | | |
| | Injured side[a,b] | 1.61 ± 0.45 | 1.45, 1.76 |
| | Uninjured side[b] | 1.43 ± 0.37 | 1.30, 1.57 |
| | Control | | |
| | Injured side | 1.29 ± 0.07 | 1.13, 1.44 |
| | Uninjured side | 1.34 ± 0.16 | 1.20, 1.48 |
| Mediolateral | | | |
| | Chronic ankle instability | | |
| | Injured side | 2.70 ± 1.01 | 2.24, 3.15 |
| | Uninjured side | 2.54 ± 0.75 | 2.13, 2.94 |
| | Control | | |
| | Injured side | 2.43 ± 0.88 | 1.99, 2.87 |
| | Uninjured side | 2.51 ± 0.93 | 2.12, 2.91 |

[a] In the anteroposterior direction, the injured side of the chronic ankle instability group took longer to reach stability than both the uninjured side of the chronic ankle instability group and both sides of the control group (group-by-side interaction: $F_{1,36} = 4.74$, $P = .036$).
[b] In the anteroposterior direction, the chronic ankle instability group took longer to reach stability than the control group (group main effect: $F_{1,36} = 9.85$, $P = .003$).

## RESULTS

### Dynamic Stabilization

A group-by-side interaction existed for APTTS ($P = .003$). The Scheffé post hoc test revealed that the injured side of the CAI group took longer to stabilize than either the uninjured side of the CAI group or both sides of the control group (Table 2a and b). For the MLTTS data, no interactions or main effects were noted.

### Kinematics

For the knee-flexion position at landing impact, a group main effect was seen ($P = .008$) (Table 3a and b). The control group had more knee flexion when impacting the ground (mean = 7.63 ± 6.11°; 95% CI = 5.41, 9.85) than the CAI group (mean = 3.21 ± 5.03°; 95% CI = 0.93, 5.50). No main effects or interactions were demonstrated for ankle plantar flexion or hip flexion.

**Table 2b. Group and Side Main Effects and Group-by-Side Interactions for Time to Stabilization in the Anteroposterior and Mediolateral Directions**

| Direction | | Value | | |
|---|---|---|---|---|
| | | Group Main Effect | Side Main Effect | Group-by-Side Interaction |
| Anteroposterior | | | | |
| | $F_{1,36}$ | 4.74 | 2.83 | 9.85 |
| | $P$ | .36 | .10 | .003 |
| | Power | .56 | .37 | .86 |
| | Effect size | 1.78 | 0.22 | 4.57 |
| Mediolateral | | | | |
| | $F_{1,36}$ | 0.28 | 0.94 | 1.153 |
| | $P$ | .60 | .76 | .29 |
| | Power | .08 | .06 | .18 |
| | Effect size | 0.16 | 0.04 | 0.31 |

**Table 3a. Ankle Plantar Flexion and Knee and Hip Flexion for the Chronic Ankle Instability and Control Groups**

| Flexion Position | Group | Flexion, ° | |
|---|---|---|---|
| | | Mean ± SD | 95% Confidence Interval |
| Ankle plantar | | | |
| | Chronic ankle instability | | |
| | Injured side | 36.14 ± 7.13 | 31.68, 40.61 |
| | Uninjured side | 36.52 ± 7.16 | 33.59, 39.46 |
| | Control | | |
| | Injured side | 36.10 ± 11.18 | 31.50, 40.70 |
| | Uninjured side | 38.98 ± 4.77 | 35.95, 42.00 |
| Knee | | | |
| | Chronic ankle instability | | |
| | Injured side | 3.45 ± 5.21[a] | 0.54, 6.37 |
| | Uninjured side | 2.97 ± 4.86[a] | 0.51, 5.43 |
| | Control | | |
| | Injured side | 6.82 ± 6.82 | 3.99, 9.66 |
| | Uninjured side | 8.44 ± 5.33 | 6.04, 10.84 |
| Hip | | | |
| | Chronic ankle instability | | |
| | Injured side | 15.72 ± 9.45 | 11.83, 19.60 |
| | Uninjured side | 16.55 ± 10.10 | 12.71, 20.39 |
| | Control | | |
| | Injured side | 16.77 ± 7.07 | 12.90, 20.66 |
| | Uninjured side | 16.89 ± 5.85 | 13.05, 20.74 |

[a] A main effect for group ($F_{1,36} = 7.93$, $P = .008$) indicated that the chronic ankle instability group landed with less knee flexion than the control group, regardless of side.

## DISCUSSION

We observed that TTS was longer in the anteroposterior direction on the injured side of the CAI group, indicating a diminished ability to stabilize on this extremity. This finding

**Table 3b. Group and Side Main Effects and Group-by-Side Interactions for Ankle Plantar Flexion and Knee and Hip Flexion**

| Flexion Position | | Flexion | | |
|---|---|---|---|---|
| | | Group Main Effect | Side Main Effect | Group-by-Side Interaction |
| Ankle plantar | | | | |
| | $F_{1,36}$ | 0.30 | 1.18 | 0.70 |
| | $P$ | .59 | .29 | .41 |
| | Power | .08 | .18 | .13 |
| | Effect size | 0.25 | 0.26 | 0.004 |
| Knee | | | | |
| | $F_{1,36}$ | 7.93 | .33 | 1.12 |
| | $P$ | .008[a] | .57 | .30 |
| | Power | .78 | .09 | .18 |
| | Effect size | 0.72 | 0.10 | 0.49 |
| Hip | | | | |
| | $F_{1,36}$ | 0.13 | 0.09 | 0.07 |
| | $P$ | .72 | .77 | .79 |
| | Power | .06 | .06 | 0.06 |
| | Effect size | 0.11 | 0.06 | 0.15 |

[a] A main effect for group ($F_{1,36} = 7.93$, $P = .008$) indicated that the chronic ankle instability group landed with less knee flexion than the control group, regardless of side.

is consistent with previous reports of increased TTS among those with ankle instability.[11–14] Simultaneously, we observed decreased sagittal knee-flexion angle at ground impact in participants with CAI. To our knowledge, we are the first to demonstrate the influence of CAI on lower extremity sagittal-plane kinematics position at ground impact during assessment of TTS. This alteration in neuromuscular control in a joint proximal to the ankle in the CAI group is consistent with findings by previous authors[7,9,27–30] and may have implications for developing new approaches to management and treatment for this condition.

It is possible that greater knee extension at impact may allow a longer period of time to dissipate and control the ground reaction forces. A lower center of mass is one element that leads to improvement in postural stability. With similar ankle and hip sagittal angles, but a decreased knee-flexion angle at impact, it is likely that the CAI participants landed with a higher center of mass than the control group, potentially contributing to the increased TTS measures in the CAI group. However, we are only reporting the kinematic positions at a single time point at the beginning of the 5-second period during which stability was assessed. Although our data suggest that the knee position at ground impact may be influencing dynamic stability after impact, additional quantification of the position and movement of the center of mass during the time period in which stability is achieved is needed to support this theory.

Disruption to the lateral ankle complex and the associated peripheral receptors from a prior injury may be responsible for diminished dynamic stability.[5] However, the associated altered knee kinematic pattern we observed suggests that CAI may create a centrally mediated alteration in neuromuscular control that manifests in part as decreased knee flexion during landing. The main effect for group that demonstrated knee position differences but not side differences suggests that the pattern of increased knee extension is created in the central nervous system.

Previous authors[29,31] have demonstrated bilateral postural control[31] and neuromuscular control[29] deficits in those with unilateral ankle injuries. We found TTS deficits only on the affected side of the CAI group, consistent with previous reports,[11–15] but the kinematic differences in the knee at ground impact were noted on both sides of the CAI group. McNitt-Gray et al[32] suggested that biarticular muscles at the knee and hip demonstrate preprogrammed activation patterns to contribute to joint stability during specific landing tasks. Additionally, centrally mediated alterations in knee-flexion angle in participants with ankle instability during landing[9] would help explain why we observed bilateral deficits in knee flexion at ground impact in our CAI group.

Caulfield et al[9] reported changes in knee sagittal-plane angle in volunteers with ankle instability during a period from 20 milliseconds before until 60 milliseconds after ground impact. Therefore, the centrally generated knee motion pattern that we observed bilaterally may be created in preparation for landing and acquiring stability. However, only the affected side of the CAI group suffered a deficit in TTS, suggesting that other mechanisms and contributions to neuromuscular control allow an individual with unilateral CAI to produce adequate dynamic stability in the unaffected limb in spite of a reduced knee-flexion angle at ground impact. Perhaps alterations in peripheral receptors in the lateral ankle complex due to existing CAI altered joint awareness, creating a feed-forward pattern affecting the knee. Clearly, additional examination of the relationships between lower extremity movement patterns at different time points before and after the landing task and TTS is needed to determine the effect of lower extremity movement patterns on dynamic stability in those with CAI.

Madigan and Pidcoe[33] demonstrated postfatigue distal-to-proximal redistribution of extensor moment production during jump landings that they hypothesized was an attempt to decrease impact force magnitude. Perhaps the altered knee position and lack of difference in ankle position that we report are manifestations of proximal redistribution and the indication of a centrally mediated alteration. Similar to our results, Madigan and Pidcoe[33] reported no changes in the sagittal-plane moment of the hip. During single-limb jump landings, disruptions to neuromuscular control such as CAI, as in our study, or fatigue[33] seem to alter knee position but not hip position.

The lack of difference in the sagittal-plane hip kinematics in our study would seem to contradict previous reports that ankle instability is associated with alterations at the hip.[27–30] Although altered knee kinematic patterns during jump landings in the presence of CAI were attributed by Caulfield et al[9] to a change in the central nervous system, perhaps the demands of a 50% jump-landing task do not require enough contribution from the hip to illustrate potential central nervous system alterations related to CAI. Future investigators should examine the muscle activation patterns of the hip musculature during tasks such as landing to determine the effect of CAI on hip function during functional tasks for assessing dynamic stability.

## Limitations

Some of the nonsignificant relationships we found were associated with low statistical power. Our sample size was calculated a priori based on our own pilot work and with a desired power level of .80, 15 participants per group were sufficient. We exceeded that by including 19 participants in each group. Upon reviewing our results, we ran a post hoc power analysis based on the differences in means and the SDs of our results. From these calculations, we found that we would have needed between 64 and 687 per group to achieve a level of power of .80 for all dependent variables. We believe such numbers of needed volunteers would be difficult and somewhat unrealistic to achieve.

In spite of these low observed power levels, we feel that the 95% CIs associated with our results strengthen the effect of our significant findings. For our nonsignificant findings, the 95% CIs displayed considerable overlap of the reported means and low effect sizes, indicating that these relationships were not significant and are likely not associated with a strong clinical difference. Conversely, our significant findings for APTTS and knee flexion angle have considerable separation in the 95% CIs and are associated with moderate to strong effect sizes. Therefore, we feel that the significant results represent the most important clinical findings from our selected comparisons.

## Clinical Implications

Our results confirm previous knowledge that TTS is increased in participants with CAI but offer additional information that knee flexion is reduced in these individuals at initial contact. These findings suggest the need to consider the influence of CAI, not only on ankle function but also on the positioning of the knee, and how these relationships influence functional, dynamic tasks. Prospective studies may be needed to quantify if these movement strategies are helpful or harmful to the ankle and determine the potential for injury to other structures throughout the lower extremity.

## CONCLUSIONS

Our purpose was to examine landing patterns during an assessment of dynamic stability during a single-limb landing task through measures of TTS and determine if volunteers with CAI exhibited altered patterns compared with matched controls. Because of the diminished dynamic stability and alterations in knee patterns during landing, clinicians and researchers may need to evaluate ankle and knee contributions to functional performance in individuals with CAI. Additional comparisons are needed to determine the magnitude of influence that knee position has on dynamic stability by examining multiple phases of the jump-landing task, including prelanding phases, the point of peak ground reaction forces, and postlanding.

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